BLACK GILL AND SHELL DISEASE IN AMERICAN LOBSTER (*Homarus americanus*) AS INDICATORS OF POLLUTION IN MASSACHUSETTS BAY AND BUZZARDS BAY, MASSACHUSETTS

by

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ABSTRACT

The incidence of "black gill" and shell disease in American lobster (*Homarus americanus*) from 12 coastal Massachusetts sites was investigated. "Black gill" and shell disease trends were similar with highest mean incidence observed in Massachusetts Bay and Buzzards Bay. Municipal and industrial wastes are implicated in conjunction with environmental conditions which enhance turbidity and bacterial growth.

Disease symptoms were not uniformly distributed throughout the lobster length range. Incidence was highest in the larger size groups indicating a possible inverse relationship with molt frequency. No significant differences in the diseases' incidence were observed between the sexes.

INTRODUCTION

"Black gill" disease symptoms were first observed in American lobster (Homarus americanus) from Buzzards Bay, MA during a mortality investigation in August, 1983. All of nine dead specimens collected from commercial lobster traps were symptomatic indicating a possible high disease frequency. As a result, a coastwide "black gill" disease survey was implemented with the goal of providing information on the frequency of occurrence of this ailment and associated shell disease in Massachusetts lobster.

"Black gill" disease is generally effected by gill fouling from noxious bottom sediments. Crustaceans, such as lobster and rock crabs, circulate suspended silt or sand particles over their gills. Consequently, sediment particles accumulate between adjacent gill lamellae and affect gill color. They provide substrate for bacterial growth with subsequent chitin deterioration, melanization, and gill tissue necrosis (Sawyer et al. 1979). This results in decreased oxygen exchange efficiency and lower resistance to secondary infection.

Shell disease is similar in etiology to "black gill" disease in that chitinoclastic (chitin-consuming) bacteria (Vibrio/Beneckea) gradually erode and pit the chitinous exoskeleton, uncover the epithelium, and create necrotic lesions (Malloy 1978; Sinderman 1970; Rosen 1970; Dow et al. 1975; Stewart 1980).

Gill blackening, melanization of tissues or appendages, shell erosion and tissue necrosis are useful qualitative indicators of the effects of ocean dumping on rock crabs, Cancer irroratus; American lobster, Homarus americanus; and shrimp, Crangon septemspinosa (Gopalan and Young 1975; Young and Pearce 1975; Bodammer and Sawyer 1981; Sawyer 1982; Sawyer et al. 1983). Although shell erosion and melanization of diseased tissue occur commonly in many crustacean species, incidence is very high near ocean disposal sites in the New York Bight.

The coincidental monitoring of "black gill" and external shell disease symptoms provides a means of validating areal variation in disease incidence if parallel trends are demonstrated. Pollution problem areas can thus be delineated. The relationship between "black gill" disease, shell disease, and known dredge spoil- and sewage-associated contaminants will be discussed.

METHODS

From 7 September to 15 November, 1983 and on 8 May, 1984, a total of 272 lobster was collected from 12 Massachusetts sites (Figure 1). Samples were obtained through ongoing Massachusetts Division of Marine Fisheries commercial lobster trap and bottom trawl assessment surveys, research traps, and a cooperating recreational lobsterman.

Samples were examined in the laboratory. Lobster were sexed and their carapace lengths measured to the nearest mm. Gills were inspected for evidence of general and localized discoloration, melanization, erosion of the chitinous covering of the gill filaments and necrosis of underlying tissue. Gills with questionable disease symptoms were flushed under running tap water to remove loose debris and reassessed for melanization and necrosis. Shell disease symptoms of shell erosion, pitting and tunneling, and ulceration were also noted.

Duncan's multiple range test for unequal sample sites (Steele and Torrie 1960) was used to determine pairs of stations significantly different at the 0.05 alpha level. The Kolmogorov-Smirnov two-sample test (Sokal and Rohlf 1969) was applied to examine the effects of size and sex on disease incidence.

Records of dump site use and scow cubic yards of dredge material dumped in Massachusetts coastal waters were obtained from the U.S. Army, Corps of Engineers (James Bajek, personal communication).[1]

Total coliform and fecal coliform bacterial counts per 100 ml seawater for selected sites along the Massachusetts coast and locations of coastal municipal sewage outfalls were obtained from the Massachusetts Department of Environmental Quality and Engineering (MDEQE, Philip Ripa and Peter Harrington, personal communication).[2]

RESULTS

Lobster sampled ranged in size from 46-98 mm carapace length; 94% of the samples were < 81 mm (minimal legal size). Analyses of "black gill" and shell disease incidence at 10 mm carapace length intervals indicate that symptoms were not uniformly distributed throughout the size frequency (Table 1). Greatest incidence occurred in the larger size ranges. Although sample sizes at extreme intervals were not adequate for reliable statistical testing, the mean carapace length of all diseased specimens was significantly larger than that of asymptomatic samples (76.4 mm vs 72.9 mm, $P = 0.029$; and 76.8 mm vs. 73.2 mm, $P = 0.018$ for "black gill" and shell diseases, respectively). Ninety-two

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percent of the "black gill" disease and 88% of the shell disease occurred in lobster which ranged from 71 to 98 mm carapace length.

"Black gill" disease incidence at six sites north of Cape Cod (stations 1-6) ranged from 0.0% to 33.3% and averaged 10.1%. Incidence at one site east of Cape Cod (station 7) was 6.5%, and at five sites in Buzzards Bay (stations 8-12) ranged from 21.7% at the head of the Bay (station 8) to 54.2% just outside New Bedford's Inner Harbor (station 12) with a mean of 35.3% (Table 2).

Shell disease incidence exhibited a similar trend averaging 4.3% (0.0%-12.5%) at stations 1-6; 0.0% at station 7; and 25.5% (4.3%-50.0%) at stations 8-12 (Table 2).

"Black gill" disease incidence at Massachusetts Bay station 2 and "black gill" and shell disease incidence at Buzzards Bay stations 10 and 12 were significantly different from most other stations (Table 3).

The effect of carapace length upon disease incidence by station was minimal. Mean carapace lengths were statistically equal at all sites except stations 3, 4, and 5 which exhibited significantly smaller mean sizes ($P = 0.05$).

No significant differences in disease incidence were observed between sexes ($P = 0.835$ and 0.454 for "black gill" and shell disease, respectively).

The locations of recently-used and known historical dredge spoil dump sites are depicted in Figure 2 along with available data on volume of material disposed. Although disposal areas are widely distributed throughout the Massachusetts inshore region, thirteen of the twenty-five sites occur in Massachusetts Bay.

The most recent MDEQE total coliform and fecal coliform bacterialogical data available for coastal seawater (Figure 3) indicate that Buzzards Bay and Massachusetts Bay, particularly Boston Harbor, exhibit the highest bacterial counts recorded from Massachusetts coastal waters. These bacterial counts coincide with the locations of large municipal coastal sewage outfalls. Those outfalls which discharge the largest volumes of sewage are located in Buzzards Bay and Massachusetts Bay (Figure 4, Table 4).

DISCUSSION

The increase in disease incidence with lobster size indicates a possible correlation with environmental exposure time. Lobster which measure from 71-98 mm carapace length may molt 0-2 times annually (Hughes and Matthiessen 1962). Smaller lobster molt at a greater frequency and are more likely to shed their shells before chitin deterioration becomes severe enough to effect necrosis of underlying tissue. Sawyer et al. (In Press) found that molting behavior depressed "black gill" disease incidence in rock crabs, *Cancer*

irroratus. Most of the lobster examined in the present study were in intermolt condition.

Mean incidence of "black gill" symptoms in Buzzards Bay was relatively high compared to sites north and east of Cape Cod. Except for one Massachusetts Bay site, off Boston Harbor (33.3% incidence), all five Buzzards Bay sites exhibited considerably higher indices than other coastal locations.

An ancillary assessment of lobster shell disease incidence exhibited a similar trend to that of "black gill" disease confirming that the disease trend is not anomalous. "Black gill" and shell disease incidence at Buzzards Bay sampling sites increased in close proximity to New Bedford Harbor. The most heavily diseased gills and acute shell disease symptoms were observed on specimens collected at sites adjacent to New Bedford Inner Harbor.

Most of the quantitative work on the "black gill" syndrome as it relates to ocean dumping was accomplished with rock crabs and included only specimens exhibiting gills which were blackened over 50% of their surface. As a result, the impact of sewage related pollution may be significantly greater than the conservatively calculated rock crab data indicate (Sawyer 1982).

Similar conservative methodology is not adaptable to American lobster which have more efficient scaphognathite (gill bailer) mechanics. Each lobster gill is serviced by a separate gill bailer which can reverse the water flow to clean particulate matter from the gills (Phillips et al. 1980). Consequently, lobster gill fouling is less severe than in rock crabs (Sawyer et al. 1979). It is therefore necessary to monitor all stages of gill fouling in order to accurately quantify "black gill" disease in lobster.

High disease incidence is generally associated with sewage and/or dredge spoil dumping areas where environmental degradation and high bacterial counts are common (Bodammer and Sawyer 1981; Sawyer 1982; Sawyer et al. 1979; Young and Pearce 1975). Lobster and crabs collected near New York Bight dumping grounds receiving large quantities of sewage sludge and dredge spoils commonly exhibited appendage and gill erosion (Young and Pearce 1975). Gopalan and Young (1975) discovered a high prevalence of 15% shell disease in shrimp, *Crangon septemspinosa*, samples from the heavily polluted New York Bight while it was only rarely observed at control sights of Beaufort, NC and Woods Hole, MA. Sawyer et al. (1984) noted gill blackening in up to 30% of the rock crabs from the New York Bight apex.

Industrial contaminants such as PCBs, heavy metals, and hydrocarbons have been found throughout Buzzards Bay (Gilbert et al. 1973) with the highest levels observed in the New Bedford Harbor region (Ellis et al., unpublished manuscript 1977; Kolek and Ceurvels 1981; Weaver 1982). The New Bedford Harbor area is also heavily polluted with domestic sewage (MDEQE, unpublished laboratory results, 1983).

The high disease incidence off Boston Harbor delineates an additional area for concern. This general region also receives large loads of domestic

sewage (Boehm 1984). Gilbert et al. (1976) and Boehm (1984) detected PCBs, heavy metals, and hydrocarbons in sediments throughout Massachusetts Bay and parts of northern Cape Cod Bay implicating sewage outfalls, dredge spoil dumping, and the Merrimac River as the major sources of these contaminants. High levels of cadmium, known to enhance "black gill" disease symptoms (Couch 1978), exist in both Massachusetts Bay and Buzzards Bay (Gilbert et al. 1976; Ellis et al. unpublished manuscript 1977).

Contaminant body burdens may produce nutritional deficiencies through interference with the physiological processes responsible for nutritional uptake or chemosensory (food sensing) behavior (Atema and Stein 1974). Nutritional deficiencies adversely affect new shell formation, hardening, and ability to repair shell damage resulting in increased disease incidence (Stewart et al. 1969; Fisher et al. 1976; Malloy 1978). Fingerman and Fingerman (1977) found that PCBs (Aroclor 1242) inhibit molting in fiddler crabs, *Uca pugilator*; however, the effect upon lobster is unknown.

Thus there are potential detrimental effects from ocean dumping of contaminated harbor dredge spoils particularly since contaminant drift has been documented in our coastal waters (Gilbert et al. 1976) and elsewhere (Elner and Hamet 1984). As reported in the New York Bight area, an anoxic layer of water may develop over disposal sites containing large amounts of sewage sludge and dredge spoils (Young and Pearce 1975). This may result in direct lobster mortality (Young 1973). Lobster which have their effective respiratory surface decreased by fouling or necrosis of gill tissue are highly vulnerable when dissolved oxygen is low. Also, the dumping of large amounts of sewage sludge and dredge spoils may decrease shelter and prey availability and thereby increase inter- and intraspecific competition which may ultimately suppress growth rate (Elner and Hamet 1984).

Although the impacts of dredge spoil dumping and municipal sewage outfalls are of primary concern, other contributing sources of pollution exist along the Massachusetts coast. These include seepage from residential cesspools and numerous other small coastal outfalls; over one hundred small outfalls are present along the Boston Harbor perimeter alone. The cumulative effect of these sources is impossible to assess; however, the high bacterial counts recorded for Massachusetts Bay and Buzzards Bay (Figure 3) and the locations of coastal shellfishing areas which are closed due to fecal contamination are indicative of the areal impact (MDEQE, unpublished laboratory results, 1983): Massachusetts Bay and Buzzards Bay (mainly New Bedford Harbor) are without doubt major problem areas.

The water exchange rate and turbidity at sampling sites are possible factors affecting disease incidence. Buzzards Bay is a comparatively closed, shallow embayment exhibiting poor circulation (Gilbert et al. 1973) and subsequently warmer bottom temperatures during summer months (Colton and Stoddard 1973). These conditions may promote and maintain bacterial growth. Buzzards Bay waters consistently contain high levels of dissolved solids (Gilbert et al. 1973). Stormy conditions apparently cause resuspension of bottom sediments. Except for the Boston Harbor area, regions sampled north and

east of Cape Cod are generally characterized by relatively open water with a greater depth range and cooler water temperatures.

The lack of historical baseline data on lobster disease incidence off the Massachusetts coast makes it impossible to assess the rate of escalation of "black gill" or shell disease or the levels of pollution below which concern would not be warranted. Also, it is not possible to determine the effect of historical indiscriminant ocean disposal on lobster habitat and its carrying capacity. Consequently, we are guided predominantly by the trends of the present study and results of studies conducted in the New York Bight area which delineate a strong relationship between high-level pollution and disease symptoms.

Industrial waste, domestic sewage, and dredge spoils present an ever present disposal problem. Sewage volume will understandably increase with the human population and harbors must be periodically dredged to maintain navigational channels. Nevertheless, scarcity of suitable habitat may be an important limiting factor to lobster distribution and abundance (Elner and Hamet 1984).

The intense fishing pressure on our coastal lobster resource in light of the lobster's distinction as supporting the most economically important single-species fishery in the Commonwealth serves to maintain an elevated concern for the future of the fishery. Prevailing lobster management rationale has inferred that consideration should be given to mitigating all potentially detrimental factors. The contribution of "black gill" and shell disease to the total annual mortality of our inshore lobster resource is unknown, however, given the value of this resource, even a small percentage loss is economically important.

LITERATURE CITED

Atema, J. and L. S. Stein. 1974. Effects of crude oil on the feeding behavior of the lobster, *Homarus americanus*. Environmental Pollution, 6:77-86.

Bodammer, J. E. and T. K. Sawyer. 1981. Aufwuchs protozoa and bacteria on the gills of the rock crab, *Cancer irroratus* Say: a survey by light and electron microscopy. Journal of Protozoology, 28:35-46.

Boehm, Paul D. 1984. Organic pollutant biogeochemistry studies northeast U.S. marine environment. Final Report Contract No. NA-83-FA-C-0002 to National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Monitoring Program, Sandy Hook Laboratory, Highlands, New Jersey. P 1-61.

Colton, J. B. and R. R. Stoddard. 1973. Bottom water temperatures on the Continental Shelf, Nova Scotia to New Jersey. NOAA Technical Report NMFS CIRC-376.

Couch, J. A. 1978. Diseases, parasites, and toxic responses of commercial penaeid shrimps of the Gulf of Mexico and South Atlantic coasts of North America. Fishery Bulletin, U.S., 76:1-44.

Dow, R. L., F. W. Bell, and D. M. Harriman. 1975. Bioeconomic relationships for the Maine lobster fishery with consideration of alternative management schemes. NOAA Technical Report, NMFS SSRF-683. 44p.

Ellis, J. P., B. C. Kelley, P. Stoffers, M. G. Fitzgerald, and C. P. Summerhayes. 1977. Data file: New Bedford Harbor, Massachusetts. Woods Hole Oceanographic Institution Technical Report WHOI-77-73.

Elner, R. W. and S. L. Hamet. 1984. The effects of ocean dumping of dredge spoils onto juvenile lobster habitat: a field evaluation. Canadian Technical Report of Fisheries and Aquatic Sciences, No. 1247: 12 p.

Fingerman, S. W. and M. Fingerman. 1977. Effects of a polychlorinated biphenyl and a polychlorinated dibenzofuran on molting of the fiddler crab, *Uca pugilator*. Bulletin of Environmental Contamination and Toxicology, 18:138-142.

Fisher, W. S., T. R. Rosemark, and E. H. Nilson. 1976. The susceptibility of cultured American lobsters to a chitolytic bacterium. Proceedings Annual Meeting World Mariculture Society. 7:511-520.

Gopalan, V. K. and J. S. Young. 1975. Incidence of shell disease in shrimps in the New York Bight. Marine Pollution Bulletin, 6:149-153.

Gilbert, T. R., A. M. Clay, and A. Barker. 1973. Site selection and study of ecological effects of disposal of dredged materials in Buzzards Bay, Massachusetts. Prepared for Department of the Army, New England Division, Corps of Engineers by New England Aquarium. 70 pp.

Gilbert, T. R., A. M. Clay, and C. A. Karp. 1976. Distribution of polluted materials in Massachusetts Bay. New England Aquarium Corporation, Central Wharf, Boston, MA.

Hughes, J. T. and G. C. Matthiessen. 1962. Observations on the biology of the American lobster Homarus americanus. Limnology and Oceanography 7, 414-421.

Kolek, A. and R. Ceurvels. 1981. Polychlorinated biphenyl (PCB) analyses of marine organisms in the New Bedford area, 1976-80. Massachusetts Division of Marine Fisheries. 34 p.

Malloy, S. C. 1978. Bacteria induced shell disease of lobster (Homarus americanus) Journal of Wildlife Diseases, 14:2-10.

Phillips, B. F., J. S. Cobb, and R. W. George. 1980. General Biology In "The Biology and Management of Lobsters" (J. S. Cobb and B. F. Phillips, ed.). Academic Press, New York. Vol. 1:1-81.

Rosen, B. 1970. Shell disease of aquatic crustaceans. In "A symposium on disease of fishes and shellfishes" (S. F. Snieszko, ed.), American Fisheries Society Special Publication, 5:409-415.

Sawyer, T. K. 1982. Distribution and seasonal incidence of "black gill" in the rock crab, Cancer irroratus. In "Ecological Stress and the New York Bight: Science and Management" (G. F. Mayer, ed.). Estuarine Research Federation, Columbia, South Carolina, 199-211.

Sawyer, T. K., S. A. MacLean, J. E. Bodammer, and B. A. Harke. 1979. Gross microscopical observations on gills of rock crabs (Cancer irroratus) and lobsters (Homarus americanus) from nearshore waters of the eastern United States. In: Proceedings of the Second Biennial Crustacean Health Work-Shop, (D. H. Lewis and J. K. Leong, ed.). Texas A & M Univ. Sea Grant 79-114, pp 68-91.

Sawyer, T. K., E. J. Lewis, M. Galasso, S. Bodammer, J. Ziskowski, D. Lear, M. O'Malley, and S. Smith. 1983. Black gill conditions in the rock crab Cancer irroratus, as indicators of ocean dumping in Atlantic coastal waters of the United States. Rapp. P.-v. Reun. Cons. int. Explor. Mer. 182:91-95.

Sawyer, T. K., E. J. Lewis, M. E. Galasso, J. J. Ziskowski. 1984. Gill fouling and parasitism in the rock crab, Cancer irroratus Say. Marine Environmental Research 14:355-369.

Sawyer, T. K., E. J. Lewis, M. E. Galasso, J. J. Ziskowski, A. L. Pacheco, and S. W. Gorski. In Press. Gill condition in the rock crab, Cancer irroratus, as an indicator of ocean health.

Sinderman, C. J. 1970. Principal diseases of marine fish and shellfish. Academic Press, New York. 368 p.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Company, San Francisco, 776 p.

Steele, R. G. and J. H. Torrie. 1960. Principles and procedures of statistics, with special reference to the biological sciences. McGraw-Hill, New York, 481 p.

Stewart, J. E., A. Dockrill, and J. W. Cornick. 1969. Effectiveness of the integument and gastric fluid as barriers against transmission of *Gaffkya homari* to the lobster, *Homarus americanus*. Journal Fisheries Research Board. Canada, 26(1):1-14.

Stewart, J. E. 1980. Diseases. *In* "The Biology and Management of Lobsters" (J. S. Cobb and B. F. Phillips, ed.). Academic, Press. New York, Vol. 1:301-342.

Weaver, G. 1982. PCB pollution in the New Bedford, Massachusetts area: a status report. Massachusetts Office of Coastal Zone Management.

Young, J. S. 1973. A marine kill in New Jersey waters. Marine Pollution Bulletin, 4:70.

Young, J. S. and J. B. Pearce. 1975. Shell disease in crabs and lobsters from New York Bight. Marine Pollution Bulletin, 6:101-105.

Figure 1. Massachusetts territorial waters with sampling stations (1-12), 1983-84.

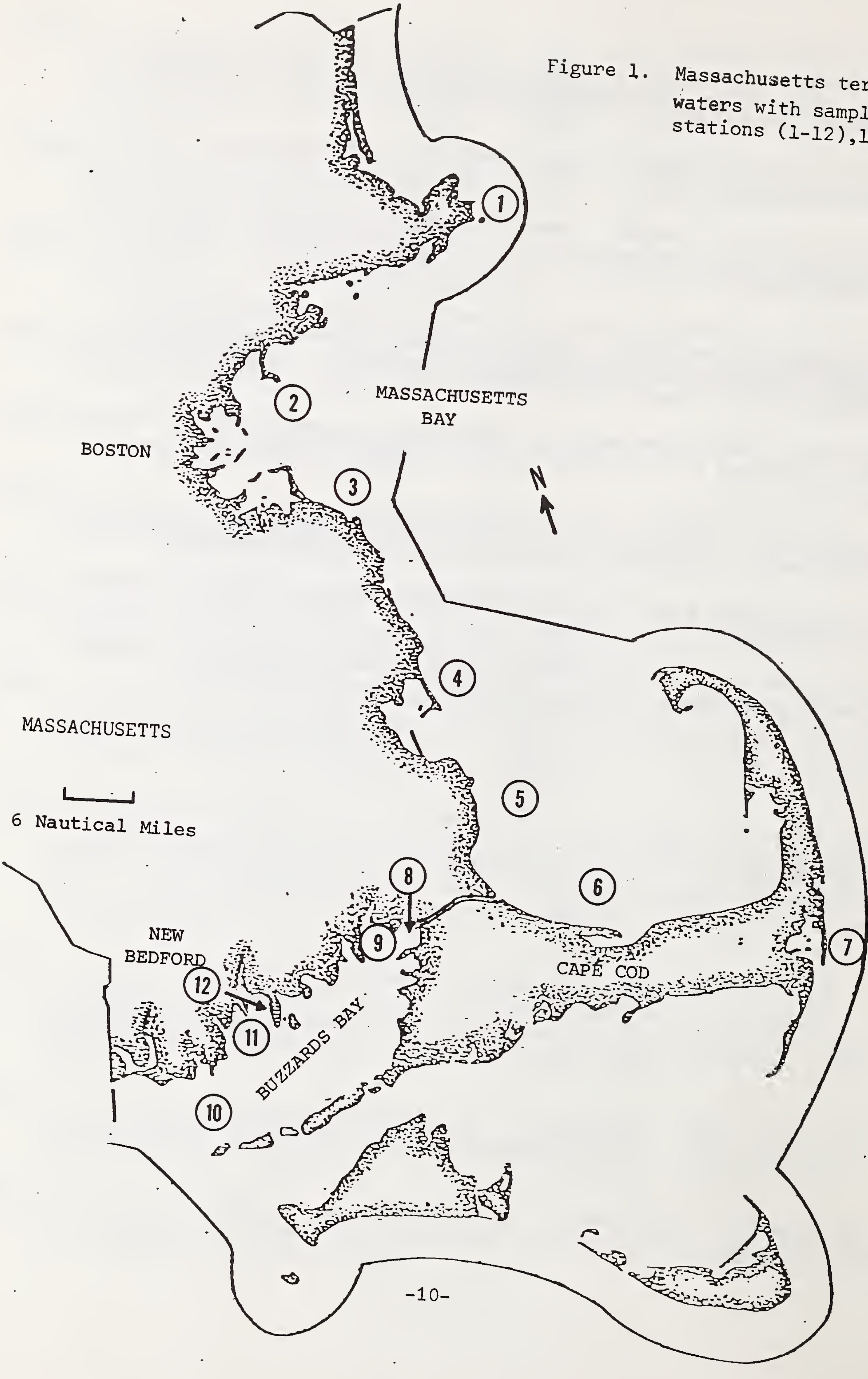
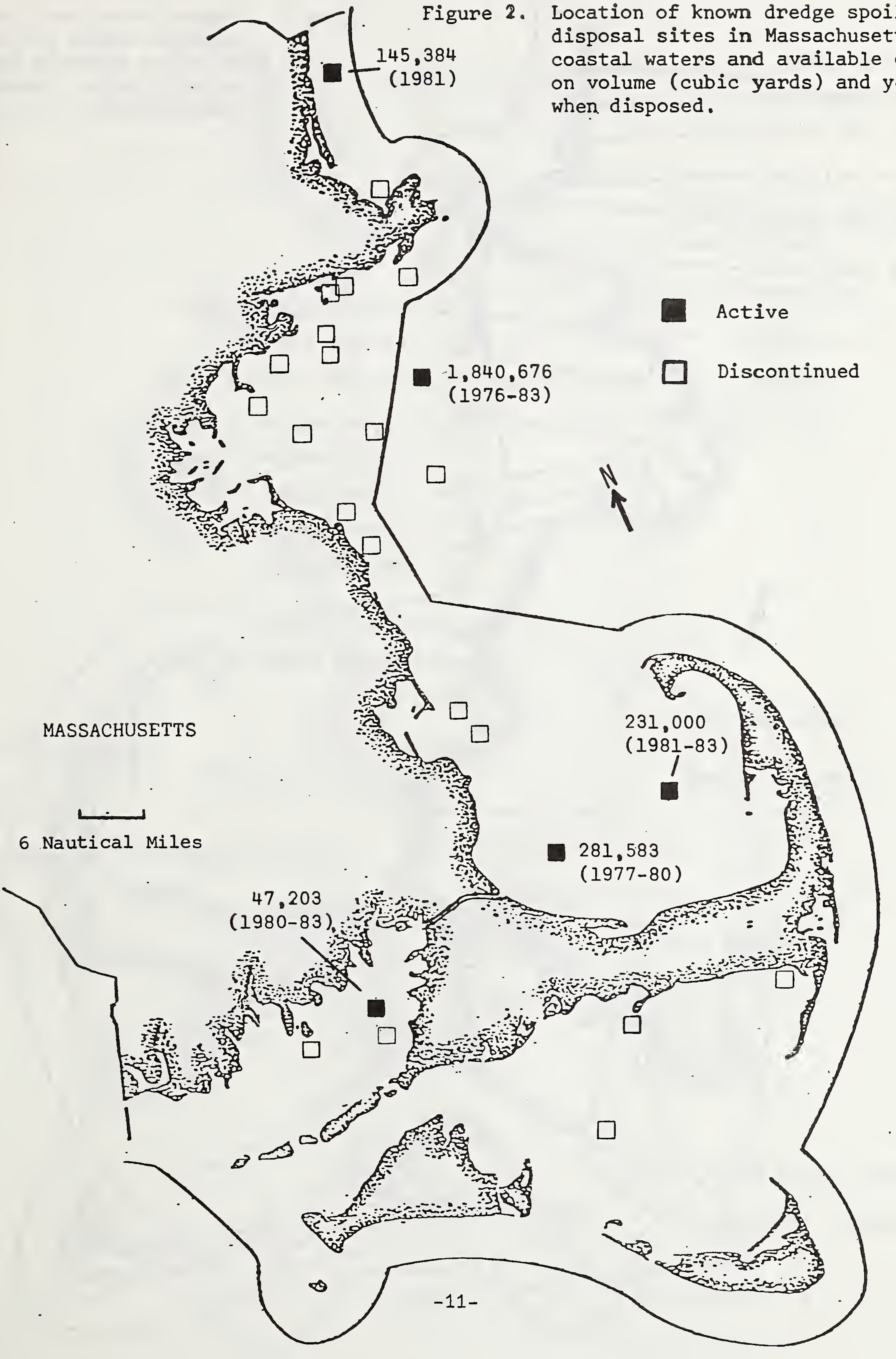


Figure 2. Location of known dredge spoil disposal sites in Massachusetts coastal waters and available data on volume (cubic yards) and years when disposed.



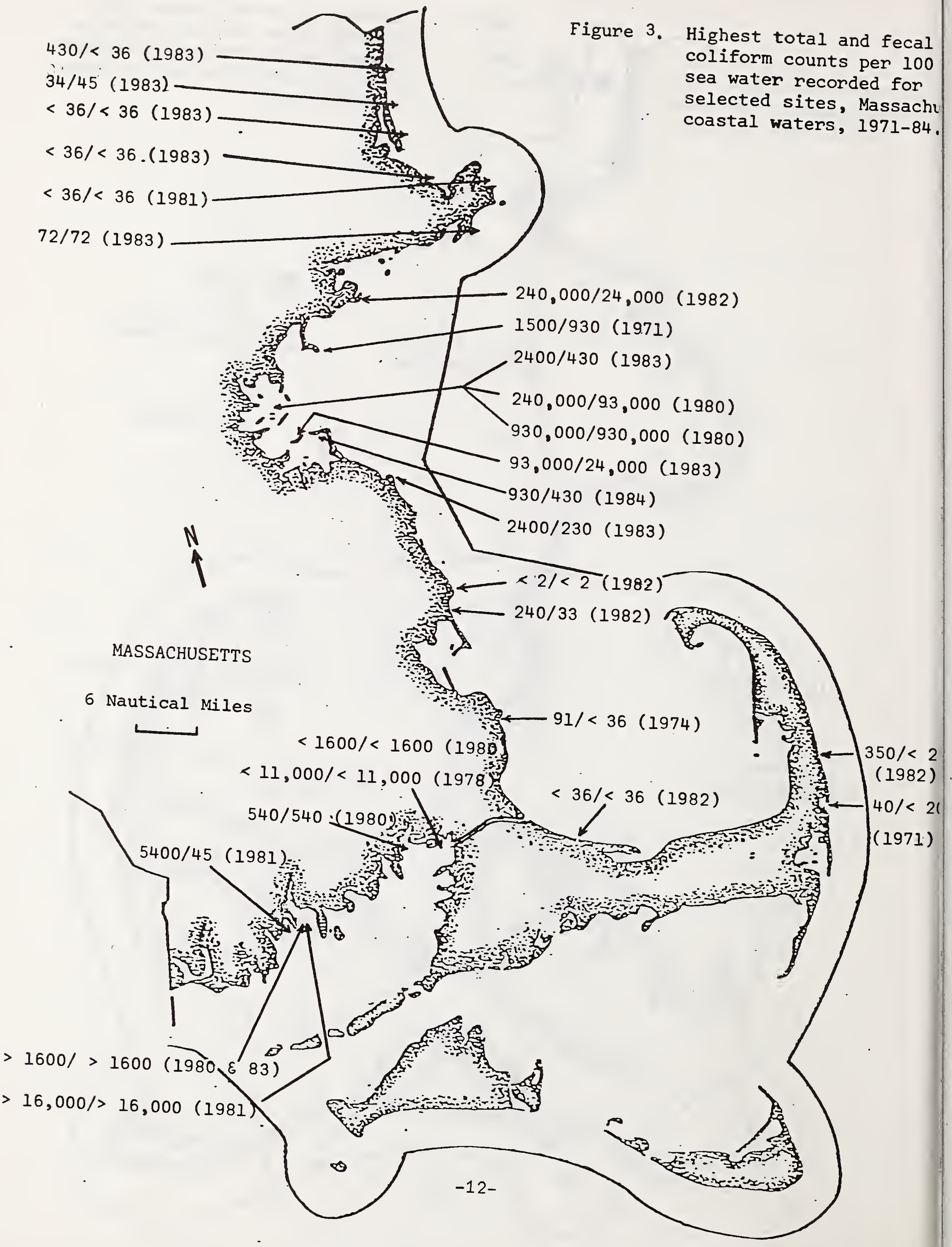


Figure 3. Highest total and fecal coliform counts per 100 sea water recorded for selected sites, Massachu coastal waters, 1971-84.

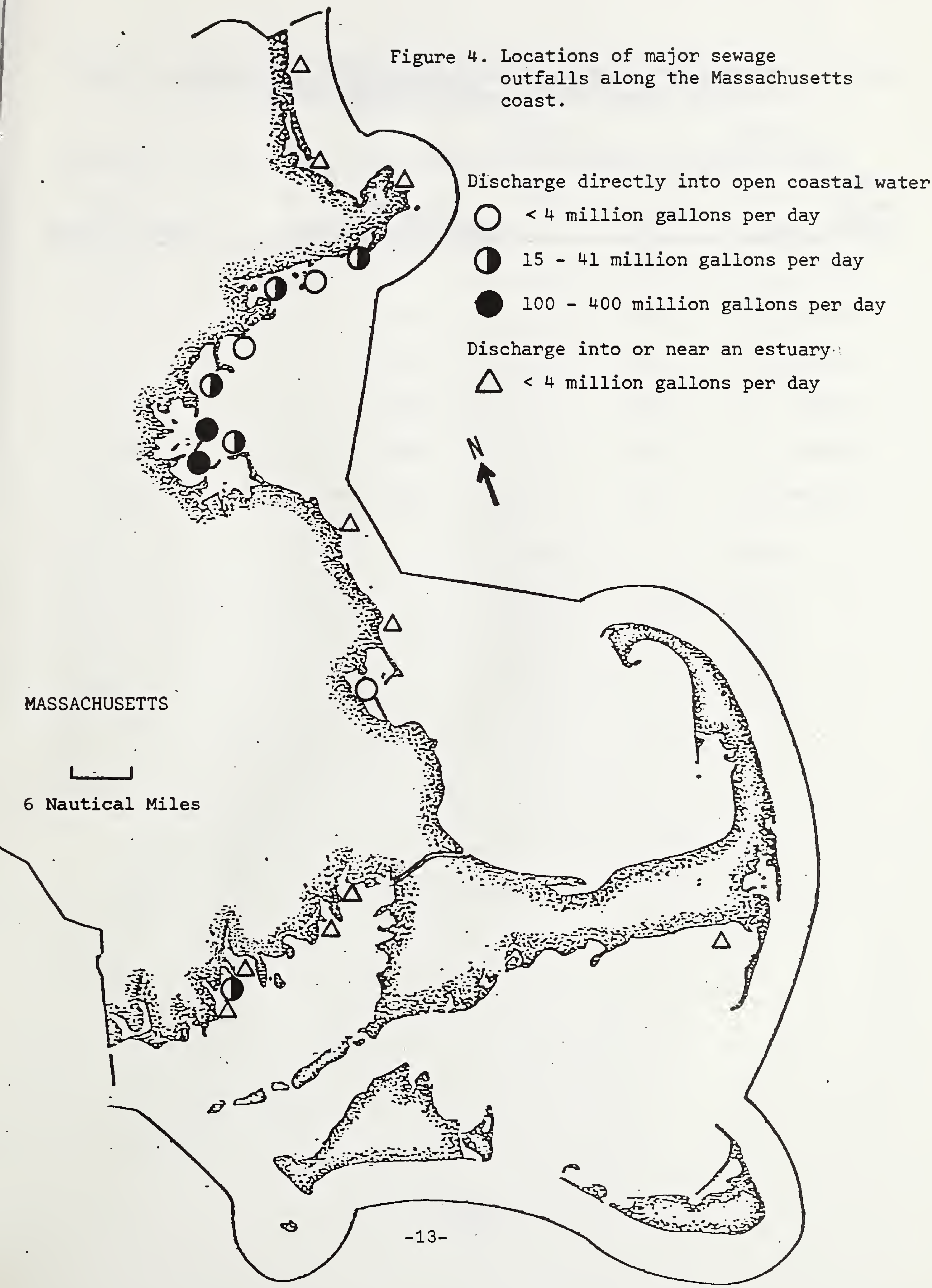


Figure 4. Locations of major sewage outfalls along the Massachusetts coast.

Table 1. "Black gill" and shell disease incidence by 10 mm carapace length intervals, Massachusetts coastal waters, 1983-84.

Carapace Length Interval (mm)	N	Percent "Black Gill" Disease	Percent Shell Disease
41-50	3	0.0	33.3
51-60	17	5.9	5.9
61-70	48	6.3	6.3
71-80	187	23.5	11.2
81-90	13	23.1	30.8
91-100	4	25.0	50.0

Table 2. "Black gill" and shell disease incidence by station, Massachusetts coastal waters, 1983-1984.

Station	N	Percent "Black Gill" Disease	Percent Shell Disease
1	28	7.1	0.0
2	24	33.3	12.5
3	26	0.0	0.0
4	31	6.5	9.7
5	4	0.0	0.0
6	26	7.7	0.0
7	31	6.5	0.0
8	23	21.7	4.3
9	8	25.0	12.5
10	35	28.6	22.9
11	12	50.0	33.3
12	24	54.2	50.0

Table 3. Mean "black gill" and shell disease incidence by station with pairs of stations significantly different at alpha = 0.05(*), Massachusetts coastal waters, 1983-84.**

"Black Gill" Disease

Mean	Station	Station								
		3	4	7	1	6	8	10	2	12
0.0	3									
6.5	4									
6.5	7									
7.1	1									
7.7	6									
21.7	8	*								
28.6	10	*	*	*	*	*				
33.3	2	*	*	*	*	*				
54.2	12	*	*	*	*	*	*	*	*	

Shell Disease

Mean	Station	Station								
		1	3	6	7	8	4	2	10	12
0.0	1									
0.0	3									
0.0	6									
0.0	7									
4.3	8									
9.7	4									
12.5	2									
22.9	10	*	*	*	*	*				
50.0	12	*	*	*	*	*	*	*	*	

**Stations 5, 9, and 11 omitted from analysis because of small sample sizes (< 23).

Table 4. Major publicly owned sewage treatment facilities discharging into open coastal or estuarine environments.

	Flow Rate (MGD)*	Treatment Type**
Boston, Deer Island	343.00	PRI.
Boston, Nut Island	112.00	PRI.
Chatham	0.44	E.A.
Dartmouth	2.90	E.A.
Fairhaven	2.07	A.S.
Hull	3.07	A.S.
Gloucester	15.00	No treatment
Ipswich	1.80	E.A.
Lynn	25.80	PRI.
Manchester	0.67	E.A.
Marion	0.34	S.P.
Marshfield	2.10	A.S.
New Bedford	30.00	PRI.
Newburyport	2.60	PRI.
Plymouth	1.75	E.A.
Rockport	0.80	E.A.
Scituate	1.00	E.A.
South Essex	41.00	PRI.
Swampscott	2.17	No treatment
Wareham	1.80	E.A.

Note: The following plants discharge into the Taunton River estuary which flows into Rhode Island coastal waters outside of the present study area.

Fall River	30.90	A.S.
Somerset	1.60	E.A.
Taunton	8.40	A.S.

*Millions of gallons per day

**PRI. - Primary treatment
A.S. - Activated sludge
E.A. - Extended aeration
S.P. - Settling pond